PINE 9

HARDWOOD CONTROL TREATMENTS TO ENHANCE NATURAL REGENERATION AND GROWTH OF LOBLOLLY-SHORTLEAF PINES IN AN UNEVEN-AGED STAND: 12-YEAR RESULTS[1]

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Abstract—To facilitate natural regeneration of loblolly (*Pinus taeda* L.) and shortleaf pines (*P. echinata* Mill.) in an overstocked, uneven-aged pine stand in southeastern Arkansas, hardwoods were controlled by either basal injection of Tordon® 101R, soil application of Velpar® L, or rotary mowing followed by a broadcast spray of Tordon® 101 applied over the hardwood stubble. After hardwood control, an improvement cut reduced merchantable pine basal area from 97 to 70 ft^2 per acre, just before a better-than-average pine seed crop. Two subsequent improvement cuts in July 1987 and June 1991 left 55 and 48 ft^2 per acre, respectively, in merchantable pine basal area. Twelve years after hardwood control, all plots had an adequate density of pine regeneration for uneven-aged stands, but dominant pine regeneration on treated plots averaged 16 ft taller and 2.2 in. larger in groundline diameter than the dominants on untreated plots.

INTRODUCTION

Although much forest acreage in the South is stocked with pine sawlogs in the overstory, little or no pine regeneration is present in the understory, even when overstory basal area is optimum (<60 ft^2 per acre) for such regeneration. Hardwood trees, shrubs, vines, and brambles invade pine sites and shade out many pines of smaller size during the early years of pine development. To compound this problem, many private nonindustrial forest landowners tend to periodically harvest their merchantable sawlog pines without controlling the hardwood component. Such harvesting practices are especially detrimental in uneven-aged pine silviculture because there must be a progression of trees from the smaller to the larger and more valuable size classes.

Private nonindustrial forest landowners are often aware of the hardwood problem on pine sites, but frequently have the misconception that hardwood control involves high-cost, intensive treatments, requiring the use of heavy mechanical equipment. As a result, productive pine sites can become dominated by low-quality hardwoods that may have little commercial value as a timber resource.

The objectives of this study were to assess the effects of low-cost hardwood control on the establishment of natural pine regeneration and to monitor the development of that regeneration to merchantable size. This paper reports the efficacy of three hardwood control treatments for enhancing pine establishment and growth 12 years after treatments were applied.

METHODS

The study was initiated in southeastern Arkansas in a mature, overstocked stand of loblolly (*Pinus taeda* L.) and shortleaf pines (*P. echinata* Mill.) that averaged 20 in. d.b.h. and contained 97 ft^2 of pine basal area per acre. The stand did not have a well-defined uneven-aged structure but did have potential for uneven-aged management. Submerchantable (<3.6 in. d.b.h.) pine density was only 63 stems per acre compared to a hardwood density of 2,350 stems per acre.

Soil on the study area is Bude (Glossaquic Fragiudalf) silt loam (USDA 1979). Sixteen contiguous plots of 0.25 acre each were established in spring 1983 with interior subplots measuring 66 by 66 ft (0.1 acre). The experiment was a randomized complete block design with four replications of each treatment. Blocking was based on merchantable pine basal area before the first improvement cut. Preharvest treatments for controlling hardwoods were assigned at random within blocks.

Hardwood control treatments were applied to plots only once, as follows:

(1) Untreated check—There was no preharvest control of hardwoods.
(2) Basal injection—All hardwoods having a groundline diameter (g.l.d.) of ≥1 in. were injected with Tordon® 101R (picloram at 0.27 lb acid equivalents (a.e.) per gal and 2,4-D at 1.0 lb a.e. per gal) at the rate of 0.03 oz per incision and one incision per inch of groundline diameter Injection was accomplished in late March 1983 with Jim-Gem® tree injectors.
(3) Soil-applied herbicide—Velpar® L (hexazinone) was dispersed using spotgun applicators at the rate of 4 lb active ingredients (a.i.) per acre on a 4- by 4-ft grid. A 50/50 solution of water/hexazinone was applied as 0.19 oz spots. Because soil texture and soil moisture affect the efficacy of hexazinone, the herbicide was dispersed in early April 1983, when there was adequate soil moisture to ensure uptake by target plants.
(4) Mow and herbicide spray—All hardwoods ≤4 in. d.b.h. were mulched using a rotary mower attached to a wheel tractor; hardwoods >4 in. d.b.h. were cut with chain saws then mulched with the mower so that no hardwoods were left standing. Plots were mowed in late May and early June 1983. Tordon 101 was applied over the hardwood stubble as a broadcast spray at the rate of 2 lb a.e. per acre in 60 gal of water per acre as soon as mowing was complete.

The initial improvement cut was completed in summer 1983 by harvesting the poorest quality trees so that residual pine

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basal area averaged 70 ft^2 per acre. A second improvement cut was completed in summer 1987, leaving 55 ft^2 per acre of merchantable pine basal area. Residual pine basal area averaged 48 ft^2 per acre following a third improvement cut in June 1991. All three improvement cuts were done operationally using rubber-tired tractors and skidding log lengths no longer than 36 ft. The objectives of the improvement cuts were to provide openings for natural pine regeneration, remove trees of poor form and quality, and improve spacing of residuals.

Pine seed crops were monitored during the first three winters after hardwood control. Pine regeneration, hardwood reestablishment, and percent ground cover were measured within nine systematically spaced circular quadrats (5.27-ft radius) per interior 0.1-acre subplot. Twelve years after hardwood control, pine seedlings (<0.6 in. d.b.h.) and saplings (0.6 to 3.5 in. d.b.h.) were counted within each sample quadrat. The two tallest (dominant) stems of pine regeneration (seedlings or saplings) per quadrat were measured for total height to 0.1 ft and g.l.d. to 0.1 in. and were assessed as being either overtopped by nonpine competition or free-to-grow. Percent ground cover of vegetative components was visually estimated on each quadrat to the nearest 10 percent. Hardwoods of seedling and sapling size were identified by species, and rootstocks were counted within each sample quadrat. A rootstock was comprised of seedling-sized single or multiple stems (clump) which obviously arose from the same root system. Hardwoods >3.5 in. d.b.h. were identified as *Acer rubrum* L. (red maple), *Cornus florida* L. (flowering dogwood), *Ilex opaca* Ait. (American holly), *Liquidambar styraciflua* L. (sweetgum), *Quercus* spp. (red oaks or white oaks), and *Sassafras albidum* (Nutt.) Nees (sassafras). All merchantable-sized pines and hardwoods were counted by 1-in. d.b.h. classes within each 0.25-acre gross plot.

Data were analyzed by analysis of variance. Percent values were analyzed following arcsine transformation, but only nontransformed values are presented. Orthogonal contrasts were used to partition mean differences among treatments as follows: (1) untreated checks versus competition control treatments; (2) effects of herbicides applied by basal injection and herbicides applied to soil versus mowing and herbicide spray; and (3) effects of herbicides applied by basal injection versus herbicides applied to soil. Treatment differences were judged significant at $\alpha = 0.05$.

RESULTS AND DISCUSSION

During winter 1983-84, following hardwood control and the first improvement cut, a better-than-average pine seed crop averaged more than 1,000,000 potentially viable seeds per acre (Cain 1988). Twelve years after hardwood control, density of pine regeneration established from that seed crop or subsequent seed crops, averaged 1,811 stems per acre on hardwood control plots, which was 307 percent more (P = 0.03) than occurred on check plots (table 1). Quadrat stocking of these pines averaged 42 percent on check plots versus 78 percent on treated plots, and that difference was statistically significant (P = 0.05).

Based strictly on density and quadrat stocking, the untreated check plots were adequately regenerated with enough pines to perpetuate uneven-aged management. However, when size of pine regeneration was considered, the untreated check plots become a less-favorable option. After 12 growing seasons, saplings accounted for more than 70

Table 1—Status of pine regeneration 12 years after hardwood control in a southeastern Arkansas uneven-aged pine stand

Hardwood control and orthogonal contrasts	Density	Quadrat stocking[a]	Total height[b]	Groundline diameter[b]	Free-to-grow[b]	Ground cover from pine regeneration
	No./acre	Percent	Feet	Inches	- - - - - - - Percent	- - - - - -
1. Check	445	42	3.61	0.51	20	2
2. Injection	2,167	84	19.94	2.88	80	31
3. Soil-applied herbicide	1,139	64	15.85	2.16	65	17
4. Mow-and-spray	2,126	86	23.08	3.06	90	37
Mean square error	819,049	.15	34.02	.73	.25	.02
P>F[c]	.07	.12	.01	.01	.06	.03
		Probabilities of a greater F-ratio				
1 vs 2+3+4	.03	.05	< .01	< .01	.02	.01
2+3 vs 4	.42	.36	.18	.32	.26	.17
2 vs 3	.14	.22	.35	.27	.47	.19

[a] (Number of occupied quadrats/total number of quadrats) x 10.
[b] Based on the tallest 250 stems per acre on sample quadrats.
[c] The probability of obtaining a larger F-ratio under the null hypothesis.

percent of pine regeneration density on treated plots but only 22 percent of pine regeneration on check plots. On the mow-and-spray plots, more than 1,900 pines per acre grew to sapling size in 12 years as compared to a range of from 778 to 1,486 pine saplings per acre on the soil-applied herbicide plots and injection plots, respectively.

For the tallest 250 stems per acre of pine regeneration, total heights averaged from 12 to 19 ft taller (P <0.01) on hardwood control plots compared to untreated check plots (table 1). Similarly, dominant pine regeneration on hardwood control plots averaged 2.2 in. larger (P <0.01) in g.l.d. compared to dominants on check plots (table 1).

After 12 growing seasons, only 20 percent of dominant pine regeneration was free-to-grow on untreated check plots compared to an average of 78 percent on hardwood control plots, and that difference was significant (P = 0.02) (table 1). Likewise, ground cover from pine regeneration was consistently higher (P = 0.01) on hardwood control plots (28 percent) versus check plots (2 percent).

When the study was initiated, the number of pines by diameter class did not exhibit the reversed-J distribution (Smith 1986) that is characteristic of uneven-aged stands, because there was no pine regeneration. However, the release of midstory pines by three improvement cuts and the ingrowth of pine regeneration during the 12-year period, resulted in a stand with an irregular uneven-aged structure (fig. 1).

Density of submerchantable-sized (<3.6 in. d.b.h.) nonpine woody competition averaged 9,035 rootstocks per acre with no differences (P = 0.49) among treatments (table 2). *Cornus florida* L., *Callicarpa americana* L. (American beautyberry), *Vaccinium* L. spp. (huckleberry), and *Acer rubrum* L. accounted for 70 percent of submerchantable-sized woody rootstock density. *Cornus florida* was the dominant species on check, inject, and soil-applied herbicide plots; *Vaccinium* was dominant on mow-and-spray plots.

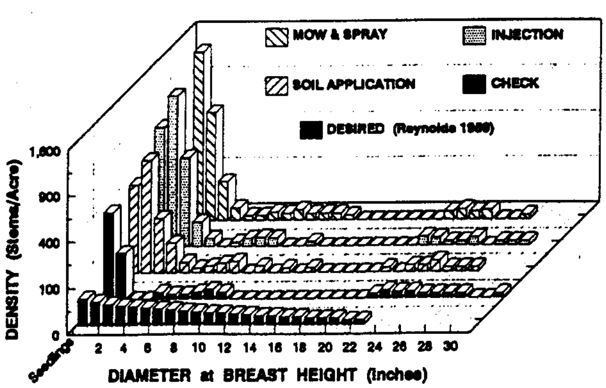

Figure 1—Diameter distribution of loblolly and shortleaf pines in a southeastern Arkansas uneven-aged pine stand, 12 years after hardwood control. Scale of the Y-axis is a square-root transformation.

Species richness (number of different species) of submerchantable-sized woody nonpine rootstocks was similar across all treatments. Actual counts of species by treatments were 21 on check plots, 23 on injection plots, 24 on soil-applied herbicide plots, and 21 on mow-and-spray plots. Ground cover from these submerchantable-sized woody plants averaged 57 percent with no differences (P = 0.84) among treatment means (table 2). These data suggest that diversity of plant species was not greatly compromised by applying herbicides 12 years earlier.

For merchantable-sized hardwoods (≥3.6 in. d.b.h.), hardwood control plots averaged 87 percent fewer(P <0.01) stems (22 per acre) compared to check plots (table 2). Some hardwoods in these merchantable size classes on inject and soil-applied herbicide plots were residuals that survived control treatments 12 years earlier.

On mow-and-spray plots where all hardwood stems were cut at groundline, *Liquidambar styraciflua* and *Cornus florida* were the only species to attain merchantable size in 12 years. On check, inject, and soil-applied herbicide plots, the dominant hardwood species in merchantable d.b.h. classes in order of prevalence were *Cornus florida*, *Acer rubrum*, and *Liquidambar styraciflua*. These species as a group accounted for 68 percent of merchantable-sized hardwoods on check plots, 95 percent on inject plots, and 85 percent on soil-applied herbicide plots. The only treatment with merchantable-sized *Quercus* spp. was the untreated check, where oaks comprised 11 percent of total stems.

Percent ground cover from merchantable-sized hardwoods ranged from only 4 percent on injection plots to 45 percent on check plots (table 2). Twelve years after treatment, all three hardwood control treatments had less (P <0.01) ground cover from merchantable-sized hardwoods when compared to check plots.

Because the forest floor was shaded by pines on mow-and-spray plots and by hardwoods on check plots, these two treatments averaged the lowest (P = 0.03) ground cover from herbaceous vegetation at 53 percent (table 2). Herbaceous ground cover on injection and soil-applied herbicide plots did not differ (P = 0.75) and averaged 76 percent.

Costs for hardwood control in this investigation were as follows (Cain 1988): Check (no cost), injection ($64 per acre), soil-applied herbicide ($100 per acre), and mow-and-spray ($105 per acre). These costs were based on $3.50 per hour minimum wage, retail prices of herbicides in 1983, and USDA Forest Service operating and replacement costs for fleet equipment (rubber-tire tractor used in mowing).

SUMMARY AND CONCLUSIONS

Density and quadrat stocking of natural pine regeneration that becomes established after an improvement cut in an uneven-aged stand may appear to be adequate without hardwood control. Nevertheless, under hardwood shade, dominant pine seedlings lingered in a suppressed condition with low vigor for 12 years. In contrast, all three methods of hardwood control compared in this study resulted in dominant pine regeneration that averaged larger in size and exhibited a more vigorous appearance when compared to dominant pine regeneration on plots without hardwood control. From 65 percent to 90 percent of dominant pine

Table 2—Status of nonpine competition 12 years after hardwood control in a southeastern Arkansas uneven-aged pine stand

Hardwood control and orthogonal contrasts	Density of stems <3.6 inches d.b.h.	Ground cover from stems <3.6 inches d.b.h.	Density of stems ≥3.6 inches d.b.h.	Ground cover from stems ≥3.6 inches d.b.h.	Ground cover from herbaceous species[a]
	No./acre	*Percent*	*No./acre*	*Percent*	
1. Check	9,570	63	163	45	54
2. Injection	8,056	52	20	4	77
3. Soil-applied herbicide	9,000	55	30	25	74
4. Mow-and-spray	9,514	58	15	10	52
Mean square error	2,274,155	.04	159	.01	.03
P>F[b]	.49	.84	< .01	< .01	.03
		Probabilities of a greater F-ratio			
1 vs 2+3+4	.43	.44	< .01	< .01	.07
2+3 vs 4	.31	.73	.23	.44	.01
2 vs 3	.40	.84	.29	.02	.75

[a] Herbaceous vegetation included grasses, sedges, forbs, vines, and semi-woody plants.
[b] The probability of obtaining a larger F-ratio under the null hypothesis.

regeneration was judged as free-to-grow on treated plots compared to only 20 percent on check plots. During a better-than-average seed year, any method of hardwood control combined with a pine improvement cut will facilitate the establishment of natural loblolly-shortleaf pine regeneration on silt loam soil, as long as residual overstory pine density and basal area are within recommended guidelines for uneven-aged management (Baker and others 1996).

Twelve years after establishment, density of natural pine regeneration was excessive (>1,400 stems per acre) when compared to published recommendations (Cain 1991, Reynolds 1959) for optimum postharvest density of submerchantable-size pines in uneven-aged stands (100 to 200 stems per acre). Nevertheless, on treated plots, where pine densities were highest and midstory hardwood densities were lowest, dominant pine regeneration exhibited a 12- to 19-ft height gain in 12 years when compared to dominant pines on check plots. Consequently, intraspecies competition among pines was less detrimental to growth of pine regeneration than the presence of overtopping hardwoods. Private nonindustrial forest landowners who wish to increase pine growth and yield would likely benefit from the low-cost hardwood control treatments tested in this study.

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